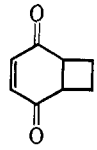
base peak at *m/e* 190 (monomer mass), does, accordingly, not show a loss of carbon dioxide.

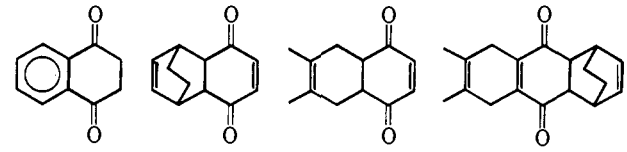
Compounds containing the structural unit VII may, however, initially also undergo an O rearrangement, followed by the consecutive loss of carbon dioxide and a hydrogen radical, leading to stable tropylium ion derivatives. Consequently, we are presently involved in the



VII

syntheses of a series of compounds containing either the structural units III or VII, in order to furnish further supporting evidence for the proposed rule.

It should finally be mentioned that compounds VIII, IX, X, and XI do not lose carbon dioxide in the mass spectrometer, thereby proving that the presence of the cyclobutane ring, condensed in the 5,6 positions to the cyclohexene-1,4-dione ring (as illustrated in structural units III and VII), is essential.



VIII IX X XI

Acknowledgment. The authors are indebted to Dr. S. Eggers for recording the mass spectra. Generous support of this work and a postgraduate grant to D. P. V. by the Council for Scientific and Industrial Research of South Africa is gratefully acknowledged.

Electron Impact Induced Rearrangements of Benztropones. 1,4-Aryl Migrations[1]

Thomas H. Kinstle, Orville L. Chapman, and Ming-ta Sung

Contribution from the Department of Chemistry, Iowa State University of Science and Technology, Ames, Iowa 50010. *Received February 13, 1967*

Abstract: A study of the electron impact induced fragmentations of 2-phenoxy-4,5-benztropone, a variety of D-, ^{18}O-, and ^{13}C-labeled derivatives, and certain model compounds has made possible a detailed description of these fragmentations. Two particularly novel fragmentations have been observed: (1) loss of OH, and (2) loss of CO, which involve both the carbonyl oxygen and the ether oxygen. These processes are correlated by demonstration of a 1,4-phenyl migration from one oxygen to the other. A corresponding phenyl migration has been shown to occur from a sulfur to an oxygen atom, but not from nitrogen to oxygen, in the analogous compounds. Loss of carbon monoxide from 2-phenoxy-4,5-benztropone gives 2-phenoxynaphthalene radical cation. Further fragmentation of this radical cation to β-naphthol radical cation and benzyne, to naphthyl cation, to phenyl cation, and to hydrocarbon cation and carbon monoxide is documented by the labeled materials. The origin of almost all fragment ions is determined by an unusually large number of metastable ions.

In the course of investigation of the photochemistry of 2-phenoxy-4,5-benztropone[2] it became necessary to prepare a variety of isotopically labeled derivatives of 2-phenoxy-4,5-benztropone. Mass spectroscopic examination of the labeled derivatives revealed a novel rearrangement induced by electron impact.[1] Prompted by this observation we have undertaken a detailed study of the behavior of 2-phenoxy-4,5-benztropone (I) and its isotopically labeled derivatives.

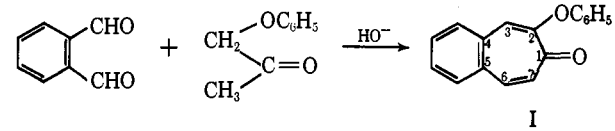
We have further expanded these investigations to include the study of possible aryl migrations from sulfur to oxygen and from nitrogen to oxygen using corresponding 2-thiophenoxy- and 2-N-methylanilino-4,5-benztropones. We have also evaluated the importance of alkyl group migrations using ^{18}O- and ^{13}C-labeled derivatives of 2-methoxy-4,5-benztropone.

(1) Portions of this work have appeared in a previous communication: O. L. Chapman, T. H. Kinstle, and M. T. Sung, *J. Am. Chem. Soc.*, **88**, 2618 (1966).

(2) O. L. Chapman, H. G. Smith, R. W. King, D. J. Pasto, and M. R. Stoner, *ibid.*, **85**, 2031 (1963).

Synthesis

Synthesis of 2-phenoxy-4,5-benztropone (I) is readily achieved by the method of Tarbell, *et al.*[3] This method also proved readily adaptable to the synthesis of isotopically labeled derivatives of 2-phenoxy-4,5-benztropone. Condensation of *o*-phthalaldehyde with phenoxyacetone in basic solution gives crude I. Treatment

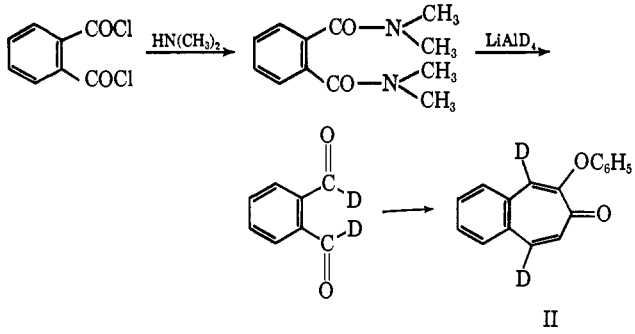


I

of phthaloyl chloride with dimethylamine gave the bisamide. Reduction of the bisamide with lithium aluminum deuteride gave *o*-phthalaldehyde with deuterium in each aldehyde group.[4] Condensation with phenoxyacetone gave 2-phenoxy-4,5-benztropone-3,6-d_2 (II).

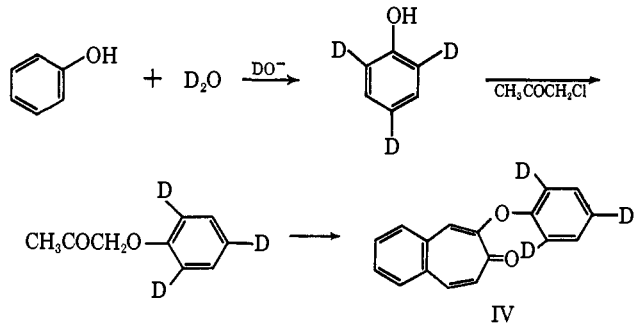
(3) D. S. Tarbell, G. P. Scott, and A. D. Kemp, *ibid.*, 72, 379 (1950).

(4) H. C. Brown and A. Tsukamoto, *ibid.*, 83, 4549 (1961).



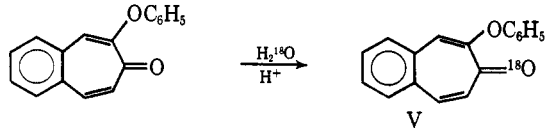
II

Equilibration of phenoxyacetone with deuterium oxide in the presence of base gave phenoxyacetone-d_5. Condensation with *o*-phthalaldehyde gave 2-phenoxy-4,5-benztropone-7-*d* (III). Equilibration of phenol with deuterium oxide in basic solution gave phenol-2,4,6-d_3. Reaction of sodium phenoxide-2,4,6-d_3 with chloroacetone gave 2,4,6-trideuteriophenoxyacetone, which on condensation gave 2-(2,4,6-trideuteriophenoxy)-4,5-benztropone (IV). Variations of the above combinations gave 2-(2,4,6-trideuteriophenoxy)-7-deuterio-4,5-benztropone and 2-(2,4,6-trideuteriophenoxy)-3,6-dideuterio-4,5-benztropone.



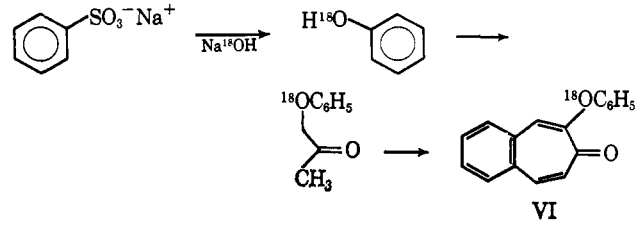
IV

Carbonyl-^{18}O-labeled 2-phenoxy-4,5-benztropone (V)



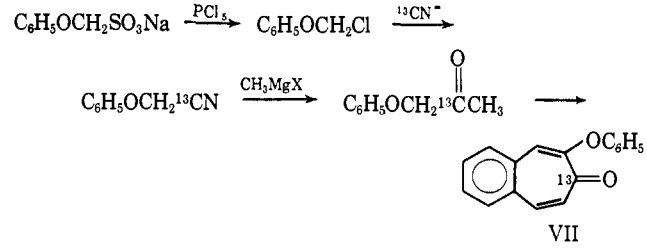
V

was prepared by acid-catalyzed exchange with ^{18}O-labeled water. Labeling the ether oxygen proved more difficult. Phenol containing oxygen-18 was prepared by fusion of sodium benzenesulfonate with ^{18}O-labeled sodium hydroxide. The ^{18}O-labeled phenol was converted to phenoxyacetone and then to 2-(^{18}O-phenoxy)-4,5-benztropone (VI).



VI

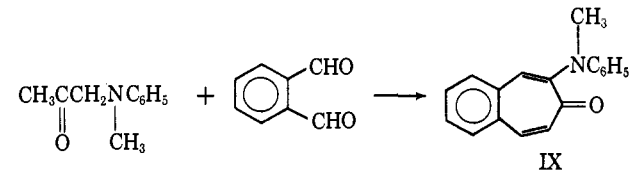
Synthesis of 2-phenoxy-4,5-benztropone-1-^{13}C (VII) utilized potassium cyanide-^{13}C. Phenol was converted to phenyl chloromethyl ether *via* the phenoxymethanesulfonate by treatment with phosphorus pentachloride.[5] Displacement of the chlorine by cyanide-^{13}C followed by Grignard reaction with methylmagnesium iodide gave phenoxyacetone-2-^{13}C. Condensation of phenoxyacetone-2-^{13}C with *o*-phthalaldehyde gave VII.



VII

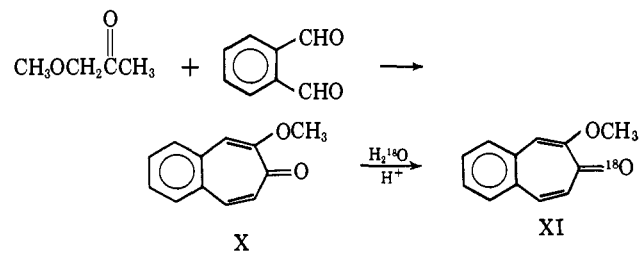
The analogous 2-thiophenoxy-4,5-benztropone (VIII) was prepared by condensation of *o*-phthalaldehyde with thiophenoxyacetone prepared in modest yield by treatment of chloroacetone with thiophenol in aqueous sodium hydroxide solution.[6] Likewise, 2-(N-methylanilino)-4,5-benztropone (IX) was prepared by the condensation of N-methylanilinoacetone with *o*-phthalaldehyde.

VIII



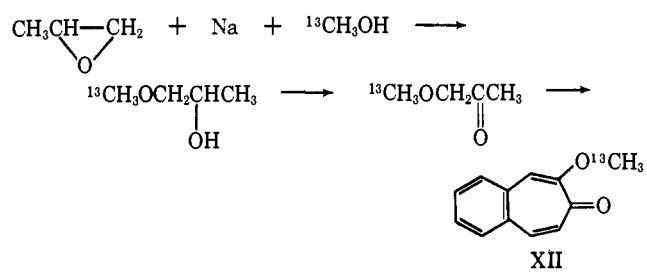
IX

2-Methoxy-4,5-benztropone (X) was prepared by the condensation of *o*-phthalaldehyde with methoxyacetone. The carbonyl-^{18}O-labeled derivative XI was prepared by acid-catalyzed exchange using ^{18}O-enriched water in tetrahydrofuran.



X XI

The synthesis of 2-(methoxy-^{13}C)-4,5-benztropone (XII) utilized methanol-^{13}C as the source of the label.



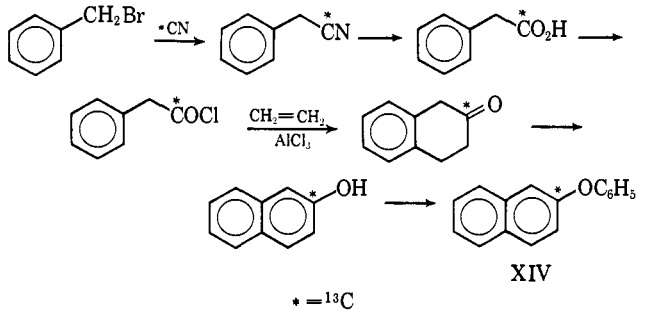
XII

(5) H. J. Barber, R. F. Fuller, M. B. Green, and H. T. Zwartouw, *J. Appl. Chem.*, 3, 266 (1953).

(6) E. G. G. Werner, *Rec. Trav. Chim.*, 68, 509 (1949).

Treatment of propylene oxide with methanol-^{13}C and sodium at 100° produced 1-(methoxy-^{13}C)-2-propanol which was oxidized to the ketone and condensed in the usual manner.

The spectra of 2-phenoxynaphthalene (XIII) and 2-phenoxynaphthalene-2-^{13}C (XIV) were obtained for comparison with the above data. Synthesis of XIV started from potassium cyanide-^{13}C. Treatment of benzyl bromide with potassium cyanide-^{13}C gave phenylacetonitrile-1-^{13}C. Hydrolysis gave carboxyl-labeled phenylacetic acid which was converted to the acid chloride. Condensation of the acid chloride with ethylene[7] gave 2-tetralone-2-^{13}C. Bromine oxidation of 2-tetralone gave 2-naphthol-2-^{13}C. Treatment of 2-naphthoxide with refluxing bromobenzene gave 2-phenoxynaphthalene-2-^{13}C (XIV).



XIV

* = ^{13}C

Results and Discussion

The 70-ev mass spectrum of 2-phenoxy-4,5-benztropone (I) is shown in Table I. The principal features are (1) a sequence of fragmentations 248 (M^+) → 220 (M − 28) → 192 → 191 → 165 each correlated by a metastable ion signal, (2) 248 (M^+) → 231 (M − 17) peak, (3) significant peaks at *m/e* 144, 127, and 77, and (4) an intense peak at *m/e* 115.

The curious M − 17 ion is due to the loss of an OH group from the molecular ion (metastable ion at 215.0) in which the hydrogen atom is derived from an *o*-hydrogen of the phenoxy group. This is clearly demonstrated by the loss of OD from the trideuteriophenoxy derivative IV (see Table I). Confirmation of the *o*-hydrogen atom involvement (as opposed to the *p*-) comes from the observed equal intensity loss of OH from 2-(4-chlorophenoxy)-4,5-benztropone. The source of the oxygen atom of the hydroxyl radical was, surprisingly, not unique. Comparison of the spectrum of either V or VI with that of I (Table I) shows that the oxygen atom is derived about equally from ether and carbonyl oxygen atoms of I. The quantitative agreement between the experiments in which the ether oxygen and the carbonyl oxygen, respectively, were labeled is quite good.

This fragmentation continues to occur at lowered ionizing voltages, and below 20 ev this M − 17 ion (*m/e* 231) becomes the most intense fragment ion. Fragmentation is considered to arise from the lowest energy ionization of 2-phenoxy-4,5-benztropone since it is the favored fragment at low ionization voltages. It seems reasonable that this lowest energy ionization involves the removal of an electron from the high-energy nonbonding orbital on the carbonyl oxygen atom. The loss of both oxygens with approximately equal facility suggests a rapid equilibration of the isomeric ions **1** and **2**. This equilibration does not appear to occur thermally.[8] A mechanism consistent with these observations is outlined in Scheme I.[9]

(7) J. H. Burckhalter and J. R. Campbell, *J. Org. Chem.*, 26, 4232 (1961).

Table I. Mass Spectra of 2-Phenoxy-4,5-benztropone and Derivatives

m/e	I	II	III	IV	V	VI	VII
251				100			
250		100		34	42	22.8	
249			100				100
248	100				100	100	91.8
233		27		27	7.0	2.4	
232			28				21.4
231	25				32.8	4.6	16.3
223				64			
222		60		20	21.5	3.4	5.9
221			61				60
220	58				75.3	68.5	52.3
219							8.1
195				20			
194		18		25			
193		20	19	14			4.4
192	18		23		31.2	19.6	25.6
191	26				40.8	25.2	28
190							7.0
189							7.0
167		4.4		8.4			
166		2.2	4.7				2.3
165	7	1.1	1.8		12.4	7.0	5.9
149							15.1
146		3.3			4.0	0.5	
145			3.5	3.2			
144	4.6				1.4	4.0	
129		19					
128			18				7.0
127	23			24.6	34.4	22.6	20.9
126							8.1
125.5				15.4			
125		18				3.0	3.5
124.5			16				
124	(M^{2+})				19.3	16.8	12.8
117		23					
116			23				
115	33			31.0	48.3	28.2	28
103		4.8					
101	7		4.8	5.6	8.6	7.1	5.9
90		7.0	3.1				
89	8.0		3.1	6.6	10.7	6.5	
80				16.0			
77	25	12	13	9.4	33.4	22.6	20
53				9.4			
52				8.0			14
51	20	14	15	9.0	28	12.1	3.5

Metastable ions in the spectrum of I[a]

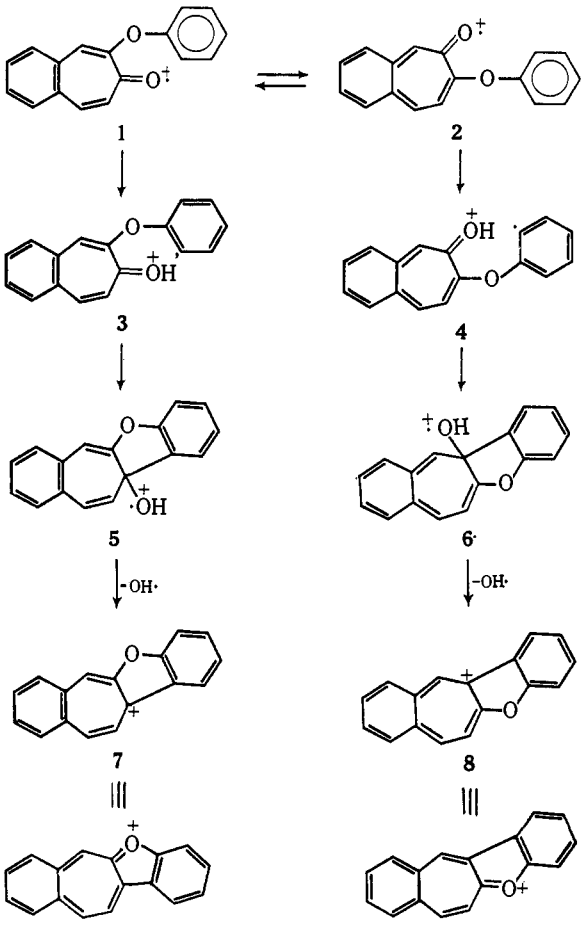
Process	m_o*	m_t*
248 → 231	215.5	215.1
248 → 220	195.0	195.5
220 → 192	167.5	167.6
191 → 165	142.5	142.7
192 → 191	190.1	190.1
127 → 126	125.1	125.1
127 → 101	80.4	80.4
115 → 89	68.8	68.5

[a] Each of the isotopically labeled derivatives of I exhibited all these metastable ions appropriately shifted.

(8) Unpublished results obtained in this laboratory.

(9) See F. W. McLafferty, *Chem. Commun.*, 78 (1966), and M. Baldwin, A. Kirkien-Konasiewicz, A. G. Loudon, A. Maccoll, and D. Smith, *ibid.*, 574 (1966), for discussions of the possible merit of localized charges in molecule ions.

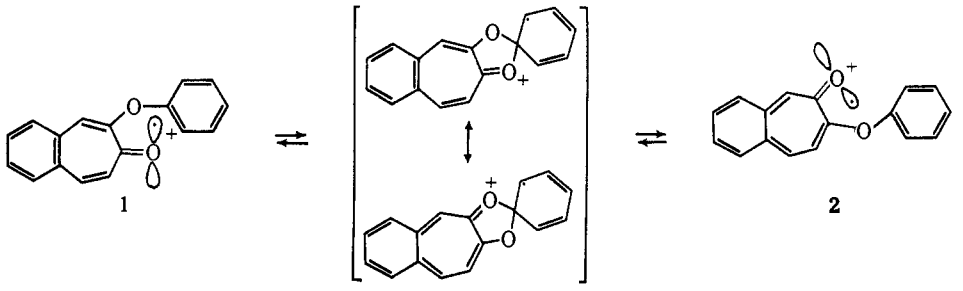
Scheme I



The investigation of aryl[10] and alkyl[11] group rearrangements upon electron impact is presently an area of vigorous activity owing to their intrinsic mechanistic interest as well as to possible limitations which they might impose on computerized element-mapping techniques.[12,13] This report constitutes the first description of an aryl migration from one oxygen atom to another upon electron impact.[14]

Related phenyl shifts have been observed in the photochemistry of 2-phenoxy-4,5-benztropone (I)[2] and certain benzoylstilbenes.[15-17] The photochemical shifts initiated by n → π* excitation of the carbonyl group provide a good model for the phenyl shift in the molecule radical ion. The half-vacant nonbonding orbital is suitably positioned for attack on the phenyl group. The intermediate formed can revert to **1** or go on to **2**. Either **1** or **2** can abstract an *o*-hydrogen from the phenoxy group giving **3** or **4**. Cyclization by addition of the aryl radical to the protonated carbonyl group gives **5** and **6**, respectively. Loss of hydroxyl radical from **5** and **6** then gives the isomeric ions **7** and **8** which do not appear to undergo further fragmentation.

It was thought probable that further evidence for this phenyl migration would be found in the ions derived from loss of carbon monoxide, and such was indeed found to be the case. In the fragmentation sequence 248 → 220 → 192 → 191 → 165, the first and second processes involve loss of carbon monoxide. Loss of carbon monoxide from the parent ion must involve both oxygen atoms (see the spectra of V and VI in Table I), but favors loss of the ether oxygen 4:1 over the carbonyl oxygen in 2-phenoxy-4,5-benztropone. This ratio agrees well with the observation that 2-phenoxy-4,5-benztropone-1-^{13}C (VII) loses 20% of the ^{13}C label in the first loss of carbon monoxide. The loss of both oxygen atoms as carbon monoxide clearly shows that the oxygen-to-oxygen phenyl shift is also important in this process. The loss of carbon monoxide from the parent ion is a relatively low energy process and is an important fragmentation mode at low ionizing voltage. The loss of OH is the only process which is more favorable at low ionizing voltage. It thus seems likely that carbon monoxide loss also occurs from the n·$^+$ ions (**1** and **2**). If one assumes that the loss of carbon monoxide involves prior isomerization to the norcaradienone-type structures (**9** and **10**), it is possible to rationalize why loss of carbon monoxide from **2** is favored over **1**. The isomerization of **2** to **10** is clearly a lower energy process than **1** to **9**. The former process produces a benzene ring while the latter destroys one.[18] The equilibrium between **1** and **2** is rapid under all conditions in which fragmentation can be observed. The ratio (1:1) of the loss of ether oxygen to the loss of carbonyl oxygen is constant in the loss of OH and the ratio (4:1) in the loss of carbon monoxide is essentially con-



(10) B. R. Webster, *Chem. Commun.*, 124 (1966), and references therein.

(11) C. Djerassi, A. M. Duffield, F. Komitsky, Jr., and L. Tökes, *J. Am. Chem. Soc.*, **88**, 860 (1966), and references therein.

(12) K. Biemann, P. Bommer, and D. M. Desiderio, *Tetrahedron Letters*, 1725 (1964).

(13) D. W. Thomas, H. Achenbach, and K. Biemann, *J. Am. Chem. Soc.*, **88**, 1537 (1966).

(14) See M. M. Green, D. S. Weinberg, and C. Djerassi, *ibid.*, **88**, 3883 (1966), for another example of interaction of a remote functional group with an ionized carbonyl group.

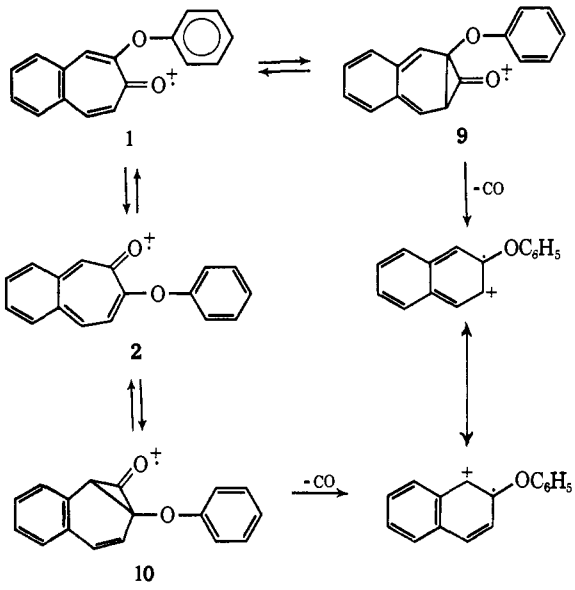
(15) H. Schmid, M. Hochweber, and H. von Halban, *Helv. Chim. Acta*, 30, 1135 (1947), and references cited therein.

(16) G. W. Griffin and E. J. O'Connell, *J. Am. Chem. Soc.*, **84**, 4148 (1962).

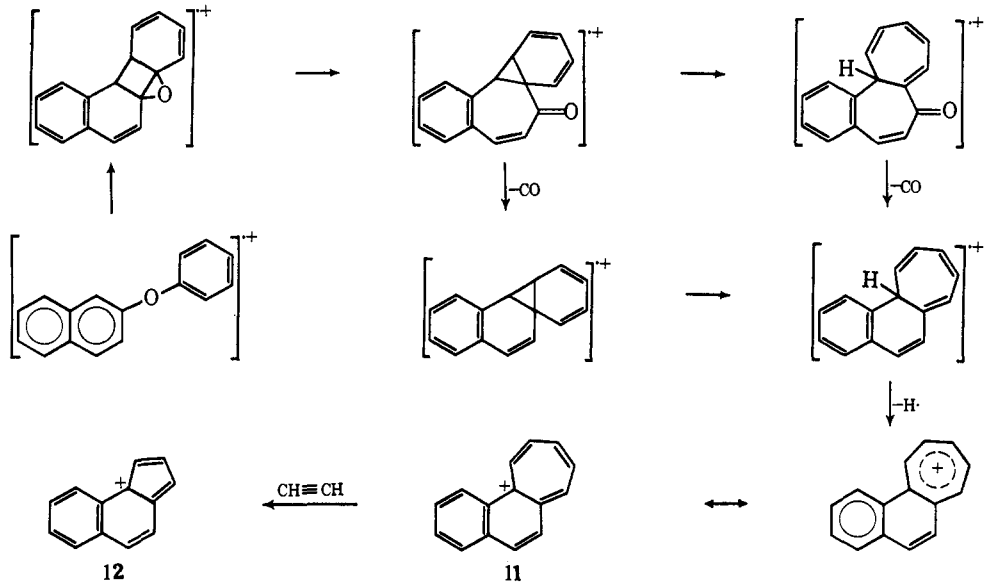
(17) H. E. Zimmerman, H. G. C. Dürr, R. G. Lewis, and S. Bram, *ibid.*, **84**, 4149 (1962).

(18) In principle, loss of CO from I might involve the ether portion of the molecule rather than the carbonyl group. This is most unlikely because of the observed efficiency of the loss of CO at low ionizing voltages. The loss of CO from diphenyl ether has an appearance potential at 12.56 ev,[19] in sharp contrast to the efficient loss of CO from I at 11 ev.

(19) P. Natalis and J. L. Franklin, *J. Phys. Chem.*, **69**, 2943 (1965).



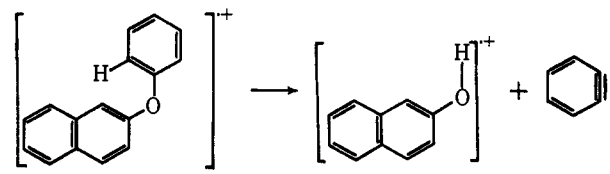
served extensive hydrogen scrambling prior to the subsequent loss of a hydrogen atom in the spectrum of IV. This scheme is consistent with the highly specific loss of the β-carbon of the β-naphthyl phenyl ether and suggests that the 192 ion thus formed should easily lose a hydrogen atom to give the 191 ion. This conversion of the 192 ion to the 191 ion is an interesting process. One would expect the cycloheptatriene derivative **11** to exhibit[20] a low specificity of loss of hydrogen *vs.* deuterium in the 192 → 191 transformation owing to equilibration of hydrogen and deuterium (by a sequence of 1,5-hydrogen transfers?) prior to tropylium ion formation. This is the case. Some deuterium is lost from the 3,6-dideuterio and trideuteriophenyl derivatives. Deuterium is not lost from the 7-deuterio derivative. The source of the hydrogen atoms in the acetylene lost from **11** is somewhat difficult to follow because of the scrambling in the cycloheptatriene derivative. In the 3,6-dideuterio and trideuteriophenyl derivatives loss of acetylene is primarily C_2HD. In the 7-deuterio deriva-



stant in each case between 70 and 18 ev (lowest ionizing voltage at which the ratios can be accurately measured).

Since so many labeled compounds were synthesized in this study, it is possible to suggest reasonable mechanisms for subsequent fragmentations and propose structures of the fragment ions. There can be no doubt that β-naphthyl phenyl ether radical cation is produced in the decomposition of **1**. The subsequent fragmentations (220 → 192 → 191 → 165, 220 → 144, 220 → 127, and 220 → 77) are all observed in the mass spectrum of β-naphthyl phenyl ether (XIII) (Table II). Furthermore, loss of carbon monoxide from the 220 ion in each case involves only the β-carbon of the naphthalene ring as shown by the spectrum of XIV in Table II. The fragmentation sequence 220 → 192 → 191 → 165 can be delineated in a structural sense by noting the loss or retention of the various labels in each fragment ion. Loss of carbon monoxide from the 220 ion requires bonding between the naphthalene nucleus and the phenyl ring at some stage prior to expulsion of carbon monoxide. A possible view of this is shown above. An alternative process involving a Fries-type rearrangement of XIII to 1-phenyl-2-naphthol prior to carbon monoxide loss is deemed less likely on the basis of the objective loss of acetylene is primarily (~90%) C_2H_2. These results clearly show that loss of acetylene in the 191 → 165 process involves primarily the seven-membered ring of **11**. The 165 ion then may be assigned the structure **12**.

The *m/e* 220 ion also gives rise to fragments ions of *m/e* 144, 127, 77, and 51. The 144 ion retains both deuterium atoms in the 3,6-dideuterio derivative and the single deuterium atom in the 7-deuterio derivative. It cleanly retains one deuterium atom in the trideuteriophenyl derivative. The residual ^{18}O label (from either carbonyl- or ether-labeled (V or VI) 2-phenoxy-4,5-benztropone) and ^{13}C label (in VII) is retained (see

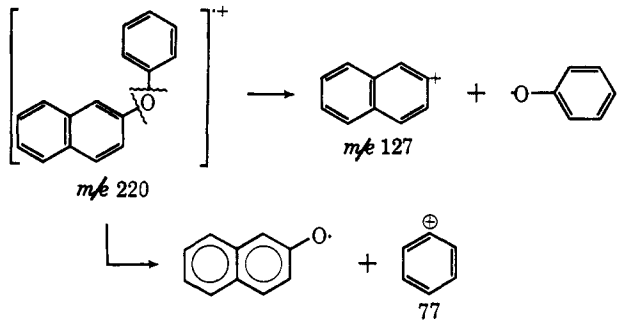


m/e 220 *m/e* 144

(20) H. M. Grubb and S. Meyerson in "Mass Spectrometry of Organic Ions," F. W. McLafferty, Ed., Academic Press Inc., New York, N. Y., 1963, p 453.

Table I). These observations are sensibly accounted for by fragmentation of the β-naphthyl phenyl ether radical cation to β-naphthol radical cation and benzyne.

In the fragmentation of the β-naphthyl phenyl ether radical cation to the *m/e* 127 ion all deuterium atoms in the 3,6-dideuterio derivative II and the 7-deuterio derivative III are retained. All deuterium atoms in the trideuteriophenyl derivative IV are lost. The ^{13}C label is retained, but all ^{18}O label from either precursor is lost (see Table I). The *m/e* 127 ion thus is the β-naphthyl cation and the other fragment is the phenoxy radical.[21] The alternate fission leads to phenyl cation



(*m/e* 77) and β-naphthoxy radical. The *m/e* 77 ion shifts to *m/e* 80 in the trideuteriophenyl derivative as expected. No other label affects the mass of this fragment. The fragment at *m/e* 51 is produced in a previously recognized fragmentation of phenyl cation.[22]

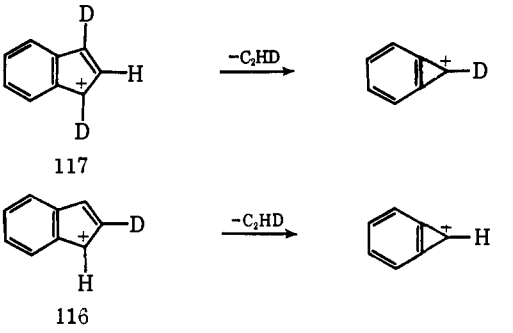
These proposed fragmentations from the *m/e* 220 ion produced from I are in very good agreement with the fragmentations observed for β-phenoxynaphthalene (XIII) itself (Table II). The spectrum of 2-phenoxynaphthalene-2-^{13}C (XIV) is in total agreement with the previously outlined fragmentation mechanisms and the spectrum of XIV recorded at 17 ev excludes the possibility of carbon monoxide loss occurring from the phenyl ring in XIII.

Table II. Mass Spectrum of β-Phenoxynaphthalene

m/e	XIII	XIV	*m/e*	XIII	XIV
221		100	128		10.2
220	100	82.5	127	9.2	12.0
192	11.2	22.5	126	3.9	3.0
191	15.1	22.5	115	8.3	17.5
166		2.5	102		2.0
165	3.6	5.8	101	3.0	3.3
145		2.5	77	6.4	12.0
144	2.8	2.0			

1-Deuterio-2-phenoxynaphthalene was prepared and studied in an attempt to pinpoint the source of the hydrogen atom lost in the *m/e* 192 → *m/e* 191 fragmentation in I. The isotope incorporation was not complete, but the results demand approximately 30% loss of deuterium, a value consistent with that found for the corresponding process in II.

The mode of formation of the fragment at *m/e* 115 is uncertain because it is not related to any ion of higher mass by a metastable ion. The *m/e* 115 ion cleanly retains all deuterium atoms from the 3,6-dideuterio (II) and 7-deuterio derivatives (III) and all other labels are lost in its formation. The *m/e* 89 ion is formed from the *m/e* 115 cation by loss of C_2H_2 (metastable ion at *m/e* 68.5). This information clearly marks the *m/e* 115 ion as the indenyl cation.[23] In accord with this view C_2HD is lost from the *m/e* 117 and *m/e* 116 ions formed from the 3,6-dideuterio and 7-deuterio derivatives, respectively.



This ion may be formed in part directly from an excited state of the molecule ion, although another likely precursor ion is *m/e* 144 since the indenyl ion is intense in the spectrum of β-phenoxynaphthalene itself. The *m/e* 191 and 165 ions are unsuitable precursors on the basis of the total deuterium retention from II and III in this ion. In an agreement with a sequence fragmentation origin, the intensity of this ion drops rapidly relative to that of other ions, including *m/e* 144, with decreased electron energies.

The only remaining ions of sufficient intensity (>5% of base) to be of interest are at *m/e* 124 and 101. The ion at *m/e* 124 is the doubly charged parent ion. This identification is secure because it shifts to a nonintegral mass (124.5) in the monodeuterio derivative. The ion at *m/e* 101 does not retain any deuterium label and is related to the *m/e* 127 ion by a metastable ion. Its composition is C_8H_4, and its structure is possibly $C_6H_4C{\equiv}C^+$.

The spectrum of 2-thiophenoxy-4,5-benztropone (VIII) (see Table III) exhibits in addition to the losses of 17 mass units (OH) and 28 mass units (CO) a loss of 33 mass units (SH), with metastable ions present at *m/e* 231.2, 211.0, and 202.0, respectively. These three fragments are produced by the lowest energy decompositions of the molecule ion and at 16 ev and lower are

Table III. Mass Spectrum of 2-Thiophenoxy-4,5-benztropone (VIII)

m/e	Rel int	*m/e*	Rel int
264	100	191	1.5
247	7.0	189	1.8
237	8.0	165	1.5
236	42.2	158	2.2
231	4.8	155	5.1
221	2.9	132 (M^{2+})	8.4
220		127	17.6
204	2.4	115	13.9
203	5.3	101	5.5
202	7.0	77	7.3
192	0.4		

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(22) J. H. Beynon, "Mass Spectrometry and Its Applications to Organic Chemistry," Elsevier Publishing Co., Amsterdam, 1960.
(23) "Catalog of Mass Spectra," American Petroleum Institute Research Project 44, Carnegie Institute of Technology, Pittsburgh, Pa., Spectrum No. 1102.

the only fragment ions observed. At these lowered ionizing potentials, the M − SH ion becomes relatively more intense than the M − OH ion, and in fact seems to increase slightly relative to M − CO. Recently the mass spectra of several aromatic sulfides have been reported to exhibit the loss of SH.[24,25] The spectrum of diphenyl sulfide, as remeasured in our laboratory, exhibits M − 32 and M − 34 ions (unlike the behavior of VIII) in addition to the M − 33 ion. More importantly, the M − 33 ion becomes insignificant at 16-ev ionizing potential, very unlike the behavior in VIII. For these reasons we propose an equilibration between SPh and OPh ions which is initiated by a phenyl migration from sulfur to oxygen. A mechanism analogous to that in Scheme I would explain the losses of OH and SH.

The loss of C=S from the molecule ion does not occur. The loss of C=S does occur to some extent from the M − 17 ion and to a lesser extent from the M − 28 ion, but neither process occurs at electron energies lower than 18 ev. It has been shown previously that these fragmentations are more difficult than the analogous losses of carbon monoxide.[26]

The spectrum of N-methylanilino derivative IX exhibits ions at M − 17 and M − 28 (with appropriate metastable signals) but does not exhibit M − 30 or M − 41 ions. Therefore we can conclude that *if* phenyl migration occurs in this system, no fragment ions result from the rearranged ion. Very probably, no rearrangement occurs.

Inspection of spectra of 2-methoxy-4,5-benztropone (X) and its labeled derivatives XI and XII lead to the conclusion that methyl migration analogous to the phenyl migration described above is not important.[27] A subsequent paper will discuss in detail the fragmentations of the methoxybenztropones.

Experimental Section

All mass spectra were obtained using an Atlas CH4 spectrometer operated with a molecular beam inlet system at temperatures less than 90°. The electron energy was varied between 11 and 70 ev and electron currents of 1–10 μa were employed.

2-Phenoxy-4,5-benztropone (I) was prepared[3] by the condensation of *o*-phthalaldehyde and phenoxyacetone in a methanol–water–sodium hydroxide solution during 3–5 days at room temperature. The solid material was then collected by filtration and recrystallized from ethanol affording 25–30% of the theoretical yield of desired product, mp 134–136°.

2-Phenoxy-4,5-benztropone-3,6-d_2 (II). N,N,N′,N′-Tetramethylphthalamide (11 g, 0.05 mole) was dissolved in 140 ml of tetrahydrofuran (distilled from lithium aluminum hydride) and cooled to 0°. Lithium aluminum deuteride (2 g, 0.05 mole) was added to the solution. The reaction mixture was stirred 24 hr at 18–20° and then poured onto ice. Sulfuric acid (10%, 5 ml) was added, and the solution was extracted with ether. The ether was removed, and the residue was dissolved in hot Skelly B. Upon cooling 2.55 g (37.5%) of phthalaldehyde-d_2, mp 52–54°, was deposited. The absence of a peak at δ 9.95 in the nmr spectrum previously assigned to the aldehydic protons was taken as evidence of the extent and position of deuteration. Phthalaldehyde-d_2 (3.3 g, 0.024 mole) and phenoxyacetone (3.7 g, 0.0246 mole) were dissolved in 350 ml of methanol, and the solution was diluted with 500 ml of water. Sodium hydroxide (0.7 g) in 15 ml of 50% methanol was then added slowly with stirring. The solution changed from yellow to cloudy cream and then to brown in color. The reaction mixture was allowed to stand at room temperature for 5 days. The yellow solid was collected by filtration. Two recrystallizations of this solid from 95% ethanol gave 1.7 g (28.3%) of 2-phenoxy-4,5-benztropone-3,6-d_2, mp 135–136°. The ultraviolet and infrared spectra are similar to those of 2-phenoxy-4,5-benztropone.

2-Phenoxy-4,5-benztropone-7-*d* (III). Phenoxyacetone (7 g) was placed in a 50-ml flask sealed with a rubber septum. Deuterium oxide (10 ml) and 10 mg of sodium carbonate were added to flask and the contents stirred with a magnetic stirrer. After 12 hr, the deuterium oxide was removed, and fresh deuterium oxide and sodium carbonate were added. The process was repeated until a total of 180 ml of deuterium oxide was used. An nmr analysis of the phenoxyacetone showed 90% deuterium exchange in the methyl group and essentially complete exchange in the methylene group.

Phenoxyacetone-d_5 (5 g, 0.032 mole) and phthalaldehyde (4.5 g, 0.33 mole) was dissolved in 160 ml of methanol-*d* and diluted with 150 ml of deuterium oxide. Sodium methoxide (1 g in 10 ml of deuterium oxide) was added slowly with stirring, and the mixture was allowed to stand for 5 days. The solid was collected and chromatographed over alumina using benzene as eluent to give 2.2 g (29%) of phenoxy-4,5-benztropone-7-*d*, mp 135–136°, after recrystallization from ethanol. The nmr spectrum showed only a multiplet in the aromatic region.

2-(2,4,6-Trideuteriophenoxy)-4,5-benztropone (IV). A mixture of phenol (10 g, 0.106 mole), sodium hydroxide (2 g, 0.05 mole), and deuterium oxide (40 ml, 2.0 moles) was heated in a sealed tube at 90° for 40 hr. After the tube was cooled and opened, the contents were made acidic and extracted into ether. The ether was removed, and the recovered phenol was retreated in the same manner to give 90% of 2,4,6-trideuteriophenol after distillation.

2,4,6-Trideuteriophenoxyacetone was prepared by the method of Hurd and Perletz.[28] A solution of chloroacetone (10 g, 0.09 mole), potassium iodide (0.3 g), and acetone (15 ml) was allowed to stand overnight. In a three-necked flask, 7 g (0.07 mole) of 2,4,6-trideuteriophenol, 2.5 g of potassium carbonate, and 50 ml of acetone were stirred and heated at reflux for 15 min, then the dropwise addition of the chloroacetone mixture was begun. After one-fourth of the mixture was added, another 2.5 g of potassium carbonate was added. This process was repeated three times. After the mixture was stirred for an additional 18 hr, the solid material was removed by filtration and washed with acetone. The acetone was removed under reduced pressure and the residue distilled under vacuum to yield 8 g (78%) of 2,4,6-trideuteriophenoxyacetone, bp 63° (0.3 mm). Condensation of this material with phthalaldehyde in the usual manner resulted in formation of 2-(2,4,6-trideuteriophenoxy)-4,5-benztropone.

2-Phenoxy-4,5-benztropone-*carbonyl*-^{18}O (V). A solution of 200 mg of 2-phenoxy-4,5-benztropone in 1 ml of dry tetrahydrofuran, 0.15 ml of $H_2{}^{18}O$ (80% enrichment), and 0.001 ml of 0.1 *N* hydrochloric acid was sealed in a glass tube and heated in a hot water bath for 40 hr. Extensive vacuum evaporation yielded 2-phenoxy-4,5-benztropone which contained (by mass spectrometry) 29% excess ^{18}O.

2-Phenoxy-4,5-benztropone-*ether*-^{18}O (VI). Phenol-^{18}O was synthesized by alkali fusion of sodium benzenesulfonate. In a 20-ml nickel crucible were placed 1 g of sodium hydroxide-^{18}O (prepared by the reaction of 0.46 g of sodium with 0.4 g of water–60% ^{18}O) and 2 g of sodium hydroxide and heat applied until the alkali melted. The temperature was allowed to fall to 230° and while stirring with a copper-encased thermometer 0.69 g of sodium benzenesulfonate was added to the crucible. During the next 5 min, an additional 2 g of benzenesulfonate was added and the temperature was raised to 270°, then to 330° for an additional 2 min. The cooled reaction mixture was dissolved in 25 ml of water and 4 ml of concentrated sulfuric acid and extracted with three 25-ml portions of ether. The ether extracts were washed with 5% sodium bicarbonate solution and extracted with dilute sodium hydroxide. Neutralization of these extracts with hydrochloric acid, extraction into ether, and evaporation of solvent yielded a crude product which was distilled to give 0.35 g of phenol-^{18}O (18% excess ^{18}O by mass spectrometry). Condensation with chloroacetone and to product ^{18}O-labeled phenoxyacetone and further condensation with phthalaldehyde using the procedures previously described resulted in the formation of desired phenoxybenztropone.

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2-(2,4,6-Trideuteriophenoxy)-4,5-benztropone-3,6-d_2. Condensation of 2,4,6-trideuteriophenoxyacetone and phthalaldehyde-d_2, the preparations of which are described above, was allowed to proceed in the manner described for the preparation of phenoxybenztropone itself to produce the desired d_5-labeled derivative.

2-(2,4,6-Trideuteriophenoxy)-4,5-benztropone-7-*d*. 2,4,6-Trideuteriophenoxyacetone (1.6 g) was treated for 8–12 hr with three successive portions of sodium carbonate (2.1 mg) and deuterium oxide (3 ml) at room temperature. The resulting phenoxyacetone-d_8 (0.7 g) and 0.8 g of phthalaldehyde were dissolved in 40 ml of methanol-*d* and 50 ml of deuterium oxide. A solution of 0.2 g of sodium hydroxide in deuterium oxide was added slowly. After standing at room temperature for 4 days, the reaction mixture was filtered and the product recrystallized from ethanol to afford 300 mg of the desired phenoxybenztropone-d_4.

Phenoxyacetone-2-^{13}C. Phenoxymethyl chloride was prepared by the reaction of phenoxymethanesulfonate and phosphorus pentachloride according to a published procedure.[5] To a stirred solution of potassium cyanide-^{13}C (0.585 g, 0.009 mole) in 2 ml of water and 3 ml of acetone was added 1.3 g (0.009 mole) of phenoxymethyl chloride in 4 ml of acetone during 1 hr. The mixture was heated to 65° and then held at 80° for an additional hour. The dark solution was poured into 10 ml of ice water containing 2 ml of 2 *N* sodium hydroxide and extracted with ether. The residue after drying and evaporation of solvent was distilled to afford 0.8 g (66%) of phenoxyacetonitrile-1-^{13}C, bp 105–110° (2.7 mm).

A solution of 0.7 g of phenoxyacetonitrile-1-^{13}C in 5 ml of ether was added to excess Grignard reagent (6 g of methyl iodide and 1 g of magnesium in 25 ml of ether) dropwise with stirring. After 18 hr, the reaction mixture was hydrolyzed with dilute hydrochloric acid and extracted with ether. The ether extracts were washed with sodium carbonate solution, dried, and evaporated to yield 0.55 g (70.5%) of phenoxyacetone-2-^{13}C, whose infrared spectrum showed twinned carbonyl absorption peaks at 5.84 and 5.97 μ.

2-Phenoxy-4,5-benztropone-1-^{13}C (VII). Crude phenoxyacetone-1-^{13}C (0.3 g) and *o*-phthalaldehyde (0.3 g) were dissolved in 30 ml of methanol and diluted with 35 ml of water. A solution of 0.1 g of sodium hydroxide in 2 ml of water was added and the mixture allowed to stand at room temperature for 3 days. The precipitate and the oil on the bottom of the flask were collected and purified by alumina chromatography (benzene–ether eluent) to afford 80 mg of 2-phenoxy-4,5-benztropone-1-^{13}C, mp 135° after recrystallization from 95% ethanol.

2-Thiophenoxy-4,5-benztropone (VIII). Thiophenoxyacetone was prepared in modest yield by treatment of chloroacetone with thiophenol in an aqueous sodium hydroxide solution. Condensation of thiophenoxyacetone (3.1 g) and *o*-phthalaldehyde (2.5 g) was affected by allowing a methanol–water solution containing these reactants and 0.5 g of sodium hydroxide to remain at room temperature for 2 days. The reaction mixture was then filtered to give dirty yellow solid and tarry material which was purified by chromatography. Elution of the material from an alumina column with benzene afforded 1.2 g of 2-thiophenoxy-4,5-benztropone. Recrystallization from 2-propanol gave yellow crystals, mp 108–109.5°.

2-(N-Methylanilino)-4,5-benztropone (IX). Phenylmethylaminoacetone was prepared according to a published procedure.[29] Condensation of this material with *o*-phthalaldehyde was affected under the same general conditions as previously discussed using a reaction time of 5 days. The crude product was very tarry and extensive chromatography was necessary.

2-Methoxy-4,5-benztropone (X) was prepared by the condensation of methoxyacetone with *o*-phthalaldehyde in basic methanol–water solution according to a published procedure.[30] The yield of product, which had mp 83–85° after recrystallization from butyl ether, was 25%.

2-Methoxy-4,5-benztropone-*carbonyl*-^{18}O (XI) was prepared by treatment of 10 mg of unlabeled material with 50 μl of water (80% ^{18}O), 2 μl of 0.1 *N* hydrochloric acid, and 100 μl of dry tetrahydrofuran at room temperature for 4 days. Evaporation to dryness under high vacuum deposited a noncrystalline material which was subjected directly to mass spectral analysis.

2-Methoxy-^{13}C-4,5-benztropone (XII). A glass tube containing 0.9 ml of propylene oxide, 0.5 ml of methanol-^{13}C, and 0.03 g of sodium was sealed and heated at 100° for 12 hr. The resulting product was distilled to give 0.9 g (82%) of colorless 1-methoxy-^{13}C-2-propanol, bp 80–100°. Oxidation of this alcohol to 1-methoxy-^{13}C-acetone was accomplished in 34% yield using aqueous sodium dichromate and sulfuric acid. Vigorous cooling was necessary to maintain a 20–25° reaction temperature during the addition. Condensation of this labeled ketone with *o*-phthalaldehyde was accomplished in 11% yield using the procedure described above for the unlabeled material. The melting point of the final product was 87° after chromatography and recrystallization from *n*-butyl ether.

2-Phenoxynaphthalene-2-^{13}C (XIV). Potassium cyanide-^{13}C (0.56 g, 0.0086 mole) was treated[31] with benzyl chloride (1.1 g, 0.009 mole) to give 0.75 g (75%) of phenoxyacetonitrile-1-^{13}C, whose infrared spectrum showed twinned nitrile absorption bonds at 4.45 and 4.56 μ. This material (0.7 g) was hydrolyzed to give 0.6 g (70%) of phenylacetic acid-1-^{13}C which was converted to the acid chloride with thionyl chloride. Phenylacetyl chloride-1-^{13}C (0.56 g, 0.004 mole) was dissolved in 11.2 ml of dry carbon disulfide and added to a stirred suspension of 0.95 g (0.004 mole) of anhydrous aluminum chloride in 15 ml of dry carbon disulfide. The mixture was cooled in an ice bath, and dry ethylene was passed in for 24 hr. The dark red mixture was poured onto ice and concentrated hydrochloric acid, and the organic material was extracted with ether, washed with dilute sodium hydroxide and water, dried, and evaporated to yield a dark residue which was distilled to give 0.35 g of 2-tetralone-2-^{13}C, bp 105–110° (2 mm). This material (0.25 g, 0.018 mole) in 2.5 ml of ether was treated with bromine (0.29 g).[32] When the addition of bromine was completed, the decolorized solution was poured into ice water; the ether layer was extracted with water and sodium carbonate, dried, and evaporated to a dark brown residue which was sublimed and crystallized from benzene–petroleum ether (bp 30–60°) to give 120 mg of a colorless halogen-free material, mp 115–117°. This β-naphthol-2-^{13}C (50 mg) was mixed[33] with potassium hydroxide (17 mg) and heated to 200° to remove all the water which formed. Bromobenzene (0.04 g) and copper powder (0.01 g) were added, and the mixture was heated to 240° for 2.5 hr. The mixture was then sublimed to yield 20 mg of 2-phenoxynaphthalene-2-^{13}C.

1-Deuterio-2-phenoxynaphthalene. 2-Naphthol-1-*d* was prepared by the method of Koller and Zollinger.[34] β-Naphthol (0.25 g) and deuterium oxide (20 ml) were sealed in a glass tube and heated at 60–70° for 4 days. After cooling, the solid was collected by filtration and purified by sublimation to give 2-naphthol-1-*d*. 1-Deuterio-2-phenoxynaphthalene was prepared by the reaction of 2-naphthol-1-*d* and bromobenzene as described above.

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